National Bureau of Standards

TECHNICAL NEWS BULLETIN

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North Pacific Radio Warning Service

THE FIRST systematic forecasts of radio propagation conditions in the North Pacific and Alaskan areas were issued recently by the National Bureau of Standards Radio Propagation Field Station in Anchorage, Alaska. This latest aid to all users of radio communications serves the same function for these areas as does the North Atlantic Radio Warning Service at Washington, D. C.

Disturbances to radio propagation have long hindered communications in the Alaskan area. Interruptions of several days are not uncommon on some high-frequency radio circuits, and these interfere seriously with the normal conduct of affairs wholly dependent on rapid communications. The disturbances are natural phenomena—resulting from the intense magnetic fields of the nearby auroral zone—and cannot be avoided. However, advance warning of their occurrence, together with forecasts of the day-to-day quality of propagation conditions, can lead to more efficient use of the shortwave radio spectrum for communications in that area.

The North Pacific Radio Warning Service is designed to supply this vital need. Special observations are carried on at Anchorage, and magnetic, ionospheric, and circuit-performance observations throughout the Alaskan and northwest Canadian area are reported promptly every day or oftener to the forecasting center. The contributing laboratories are at Point Barrow, Fairbanks, Sitka, and Adak in Alaska, and Prince Rupert in Canada. In addition, the Warning Service at Anchorage has available up-to-date solar activity information and other data sent regularly from NBS in Washington. The station is staffed by specially trained forecasters and observers and will eventually operate on a 24-hour basis.

At present, the NBS service makes available to operators of communication systems an advance forecast applicable to radio transmissions in three service areas illustrated by the following typical paths: from Alaska to Seattle and San Francisco, from Alaska to the Aleutians and Tokyo, and within Alaska. The forecast, which is revised and reissued twice each week in order to take advantage of the latest observations, lists the likely periods of disturbance in the 25 days after issue. A specific estimate of the quality of radio propagation conditions for the first 7 days of the forecast period is also included. These semiweekly advance forecasts may differ from the forecasts for the North Atlantic issued in Washington either because the effects of magnetic and ionospheric activity on radio propagation are expected to be different in the two areas, or because the data available at the two forecasting centers are not always the same. Distribution of the forecasts is greatly speeded since the forecasting service is within the area of intended coverage.

Other types of forecasts are being prepared. One is a twice-daily forecast of conditions on the Anchorage-Seattle radio circuit, which has had a 6-month test with limited distribution. NBS is also testing regional forecasts for each of the three North Pacific areas.

Site of the National Bureau of Standards new North Pacific Radio Warning Service at Anchorage, Alaska. The building houses the forecasting center and transmitting, receiving, and recording equipment. The antenna system shown is used in monitoring the field strength of long-distance radio signals.

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U. S. Department of Commerce

Charles Sawyer, *Secretary*

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Contents

The communications operator receives the forecast in terms of "expected quality" of radio propagation conditions. Basically, however, the forecasts are of variations in the intensity and direction of the earth's magnetic field. These variations are closely associated with abnormal conditions in the ionosphere—the radio-reflecting layers in the upper atmosphere. The layers, in turn, affect the propagation of specific radio transmissions.

Remarkably successful predictions of the gross characteristics of the ionospheric layers many months in advance have been made by the NBS Central Radio Propagation Laboratory for about a decade in a form convenient for calculating the utilization of the ionosphere for communications. The shorter time variations, however, are more difficult to predict. They are larger and more rapid in the zone of intense auroral activity, which includes the Alaskan area, and in these latitudes ionospheric observation stations are too widely spaced to permit the isolation of local effects. Thus, it is not now possible to forecast ionospheric characteristics in fine detail.

Practical radio circuit "quality" includes many types of effects, but it is found that the indices of quality compare more closely with magnetic disturbance variations than with any other single ionospheric characteristic. Therefore, the magnetic condition is given most weight in radio disturbance forecasting. The magnetically disturbed periods can often be forecast several days or weeks in advance from solar-terrestrial relationships or from the marked tendency for magnetic disturbances to recur at about 27-day intervals. Occasionally a forecast can be made a few hours in advance of the beginning of a severe disturbance—if a very intense solar flare is observed, for instance.

Because both magnetically disturbed and quiet periods tend to last several days, the general level of magnetic disturbance can usually be estimated for a few hours or a day ahead. These short-term magnetic forecasts are interpreted in the light of current ionospheric and radio propagation observations and result in a prediction of the anomalies that can be expected to develop in the ensuing 12 to 24 hours. The degree of success of these estimates varies widely, just as does the strength of the various correlations used. About 85 percent of the predictions of disturbances are correct; and 90 percent of the disturbed days are predicted in short-term forecasts, an appreciably better record than that attained by the advance forecasts.

With the establishment of this second warning center at Anchorage, the Central Radio Propagation Laboratory of the National Bureau of Standards is striving for more up-to-date, more accurate, and more easily distributed forecasts of radio propagation conditions. Moreover, the well-known difficulties of communications in the Alaskan area make quite appropriate the location of a radio warning service at Anchorage. At the same time, it is clear that much research and analysis remain to be done before the forecasts can be sufficiently specific and still agree with practical experience.

Lunar Reflection of UHF Communications

A RADIO message was transmitted for the first time by lunar reflection during a recent cooperative experiment conducted by the National Bureau of Standards and the Collins Radio Co. On November 8, 1951, ultrahigh-frequency signals that had been reflected from the moon were received by the NBS field station at Sterling, Va., after having been transmitted from Cedar Rapids, Iowa. Those participating in the experiment were P. G. Sulzer, G. F. Montgomery, and Ross Bateman of the Bureau's Central Radio Propagation Laboratory and I. H. Gerks of the Collins Radio Co.

Radio waves had been reflected from the moon before, but they were usually received at or near the point of origin. In the NBS-Collins Radio experiment, on the other hand, the signals were transmitted so as to be received at a site 775 miles from the transmitter after reflection from the moon. The operating frequency was 418 megacycles, generated by a 20-kilowatt transmitter. Because the transmitting antenna in Cedar Rapids was a fixed structure, lunar reflection could be accomplished only while the disk of the moon was in the beam of radio energy (a period of approximately one-half hour). The antenna at Sterling could be rotated and turned in the direction of maximum signal strength.

Reflection of the signals apparently began as soon as the leading edge of the lunar disk entered the radio beam. The receiving antenna was rotated until the maximum signal strength was obtained—in a position pointing directly toward the moon. As the moon continued to move across the radio beam, the received signal strength increased. About 10 minutes after the initial contact, the signal strength reached its highest value. The operators in Cedar Rapids then hand-keyed the signal in Morse Code and transmitted the historic message, "What hath God wrought!". The intensity remained at this maximum level for another 10 minutes and then began to decrease as the moon passed out of the radio beam. The greatest signal strength received was about one-millionth as strong as the signal received by most commercial television receivers.

To verify the fact that the signal was reflected by the moon, the actual transmission delay was compared with the theoretical value. This value was determined from the geometry of the experiment—the relative positions of the transmitter, the moon, and the receiver—and the known speed of radio waves. The 2.5-second time interval that was measured agreed approximately with the theory.

The NBS-Collins Radio experiment thus provides additional information confirming the possibility that the moon can be used as a reflector for short-wave radio transmission during those times it would be in the proper position for reflection. Use of the moon as a reflector would have the advantage that the transmissions would be free from interruption. In present long-range communications, the ionosphere is used as a reflector. This layer of electrically charged air, 100 to 350 kilometers above the earth's surface, sometimes undergoes radical changes during "ionospheric storms". When this happens, the long-range communication is partially or completely interrupted. If UHF were used, however, employing the moon as a reflector, these radio storms would have little effect on radio transmissions. Moreover, the moon would not have to be optically visible to act as a reflector, as clouds or other meteorological conditions do not affect the radio beam seriously.

As a result of these experiments, it is believed that a dependable radio system may be possible if the transmitter and receiver were engineered for the specific purpose.

Pictorial representation of the lunar reflection experiment conducted by NBS and the Collins Radio Co. An ultra-high frequency transmitter in Cedar Rapids (left) generated 20 kilowatts of power at a frequency of 418 megacycles. A horn-shaped antenna, 24 by 25 feet at one end, about 2 feet square at the other, and 70 feet long, directed the radio energy toward the moon. The signals were received 774 miles away, by a parabolic antenna, 31 feet in diameter (right), located in Sterling, Va. Because the Cedar Rapids antenna was a permanent structure, lunar reflection could occur only while the disk of the moon was in the radio beam. The total time interval between transmitted and received signal was about 2.5 seconds.

A Free-Floating Automatic Weather Station

A FREE-floating buoy-type weather station, developed by the National Bureau of Standards for the Navy Bureau of Ships during World War II, reports weather data by radio automatically and unattended. Designed by Percival D. Lowell and William Hakkarinen of the NBS electronics laboratory, the NBS buoy automatic weather station incorporates various weather-responsive devices to switch a radio transmitter on and off at rates that can be translated by a receiving station into temperature, pressure, and wind data. Information is transmitted in predetermined sequence at intervals of 3 hours. Self-contained batteries provide sufficient power for reliable operation at over-water distances up to 400 miles.

The station consists essentially of a timing mechanism, several weather-responsive devices, a relaxation or keying oscillator, and a simple two-stage radio transmitter. The weather-responsive devices cause associated resistors to vary with changes in weather conditions. At 3-hour intervals the timing mechanism, a modified automobile-type electric clock, turns the station on. While a program selector switch inserts one weather resistor after another into the keying-oscillator circuit in predetermined sequence, a relay in the plate circuit of the keying oscillator switches the transmitter on and off at a rate proportional to the value of the particular resistor. Most of the components are mechanically simple, and the electronic circuits are straightforward and conventional.

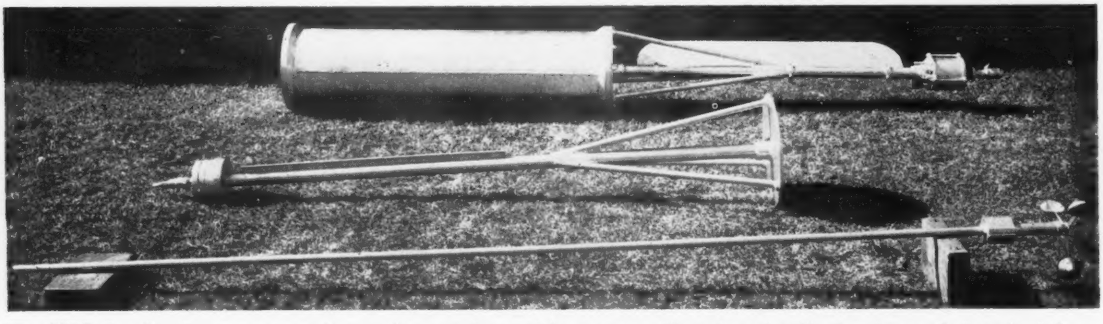
Twenty-seven feet in over-all length and weighing 280 pounds, the station centers mechanically around a buoy cylinder 5 feet long and 16½ inches in diameter. Fastened to the bottom of the cylinder is an 8-foot tail pipe ending in 40 pounds of lead ballast. On top of the buoy cylinder is a 7-foot superstructure, above which an antenna extends another 7 feet. At the junction of the antenna and the superstructure is an antenna tuning house, while an anemometer is supported at the top of the antenna. Housed in the buoy cylinder are the rest of the electronic components and weather-responsive elements, as well as the batteries.

Each transmission lasts about 10 minutes. First comes an "attention" signal, consisting of a series of rapid pulses easily recognizable by the listening station operator. Transmitted next is a "reference" signal; this will be of constant pulse rate in the absence of transmitter damage or aging, and any variation in pulse rate indicates a need for calibration corrections of the other signals. An "identification" signal follows, the rate of which is characteristic of the particular weather station. All of these signals result from switching appropriate resistors into the relaxation oscillator circuit. The various meteorological signals are next transmitted. With completion of the program, the selector switch disconnects all elements and turns off the transmitter. The clock mechanism, however, continues to run and at the proper time starts the sequence again.

Five meteorological variables are reported by the standard model of the weather station: air temperature, water temperature, air pressure, wind speed, and wind direction. Five different devices, in combination with the relaxation oscillator, key the transmitter at rates corresponding to each of these variables.

The air-temperature and water-temperature elements each consist of a temperature-responsive ceramic resistor. Mounted inside the buoy cylinder, the water temperature element attains the temperature of the water because of conduction through the cylinder walls. The air temperature element, at the bottom of the antenna tuning house, is protected by a louvered shield.

The barometric unit, of the aneroid type, is located inside the buoy cylinder. Prior to transmission of the pressure signal the indicating arm moves freely over, but not in contact with, 50 contacts connected to resistors. A clamping magnet, energized during transmis-



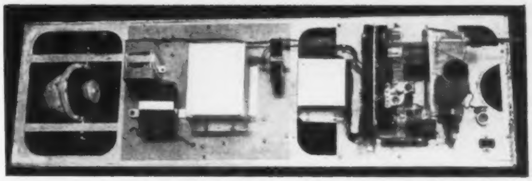
The NBS floating-buoy automatic weather station, with antenna (front) and tail pipe (center) detached from main assembly (rear). Powered by self-contained batteries, the unattended station will transmit coded weather reports by radio at 3-hour intervals for 30 days. The cylindrical buoy (rear center) houses most of the electronic equipment and weather-responsive elements, while the superstructure (rear right) supports the wind vane, an antenna-tuning housing, the transmitting antenna, and the anemometer (front right). An 8-foot tail pipe (center) with 40 pounds of lead ballast extends downward from the bottom of the cylinder.

sion of the pressure signal, holds the barometer indicating arm against the contact over which it has located itself.

The air-speed indicating mechanism differs from the others in that no variation of resistance is involved. Instead, an electrical contact is made with every revolution of the anemometer, and this contact keys the transmitter directly. By reference to the anemometer calibration, the transmitter pulse rate gives the air speed.

The wind direction indication from the free-floating buoy, initially a perplexing problem, was accomplished by letting the whole buoy serve as a highly damped weather vane. While a rudder on the buoy superstructure keeps the buoy oriented in the direction of the wind, a direction indication is given by a modified aircraft-type magnetic compass inside the buoy. Immediately above the master compass needle, which is sealed in liquid, a slave needle rotates over 36 resistor-connected contacts mounted at 10-degree intervals. During transmission of wind direction, a clamping solenoid holds the slave needle against the contact toward which it is pointed.

Several other design features are noteworthy. A combination of two special devices permits the inside of the buoy to attain atmospheric pressure, yet prevents water from entering. A solenoid-actuated valve located in the antenna tuning house is energized during the entire transmission period, so that air pressure inside the buoy equals that outside when the pressure signal is transmitted. An electrode supported by an insulator is arranged so that, if the tuning house becomes submerged or swamped, the conductivity of the sea water short-circuits the air-valve solenoid. This short-circuit closes the air valve before water can enter the buoy, and keeps it closed until the water subsides.



The main equipment panel, which fits inside the buoy cylinder, carries most of the electronic and weather-responsive components, including the radio transmitter and keying oscillator (right) and compass for indicating wind direction (left). (In normal operation the panel, like the buoy, is vertical, with compass downward).

A special watertight magnetic coupling, which transmits anemometer rotation to the contact mechanism inside the buoy, solved another design problem. This coupling, at the bottom of the anemometer shaft, consists of a small but powerful permanent magnet driving a slave magnet on the other side of a watertight bulkhead. The slave magnet in turn operates the keying mechanism.

The radio transmitter, as well as the 1-tube relaxation oscillator, is simple and conventional. A crystal oscillator drives a beam-power amplifier to give a radiated output of about 20 watts on a frequency near 5 megacycles. The battery pack provides power for 30 days' unattended operation.

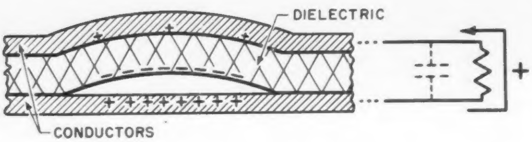
Noise-Free Instrument Cable

AN INSTRUMENT CABLE free of spurious electrical signals due to mechanical shock and vibration has been developed by Dr. T. A. Perls of the National Bureau of Standards Office of Basic Instrumentation. The noise-free cable is the result of a recent study of spurious cable signals, which was carried out as part of a program of basic instrumentation sponsored at NBS by the Department of Defense and the Atomic Energy Commission. In the course of the investigation, a detailed theoretical explanation was formulated for the generation of the spurious signals.

These signals, or "noise voltages", present a problem in many types of instrumentation work where cables are subjected to mechanical forces. They interfere with measurements of pressure in underwater explosion and air-blast research and with determination of acceleration in shock and vibration studies. They also adversely affect the performance of crystal-type microphones, hearing aids, and phonograph pickups and of many other high-impedance devices in the fields of communication, measurement, and control. Until now, the mechanism of the noise generation has not been well understood and has been assumed to be somehow related to piezoelectric or converse electrostrictive effects, changes in the electrical constants of the cable, or separation of electrical charges by friction.

In connection with the application of a piezoelectric accelerometer recently developed at NBS, it became necessary to reduce as much as possible the spurious signals due to motion of the cable. Experiments were therefore set up to compare the performance under dynamic stress of various experimental and commercial coaxial cables consisting of an inner conductor, an insulating dielectric, and a conducting shield. The cables were connected between a small piezoelectric accelerometer and a cathode follower, and the output of the cathode follower was recorded through a d-c amplifier on a direct-inking oscillograph. The standard test for cable noise consisted in grasping a short section of the cable and subjecting it to severe strains by twisting and bending, while making sure that no strains or motion were transmitted to the accelerometer itself. Another test consisted in alternately compressing and releasing a short section of the cable with a pair of pliers.

It was found that standard microphone or phonograph pick-up cable gave noise signals under these conditions as high as 500 millivolts peak-to-peak. However, the noise was definitely lowered (to about 60 millivolts peak-to-peak) by tightening the braided shield over the dielectric, thus improving the contact between the dielectric and the shield.



Schematic diagram showing how a noise current is produced in a coaxial cable by the relative motion of the conductors and the dielectric. When a temporary separation occurs between a small region on the surface of the dielectric and either conductor (e. g., the lower one), a separation of charges takes place, resulting in a surface charge on the dielectric and an opposite "bound" charge on the conductor. A portion of this charge is redistributed by flowing through the terminal impedance of the cable, so that it ultimately appears on the other conductor of the cable at a point opposite the separated charge on the dielectric.

A colloidal suspension of graphite in benzene was then applied, first to the outside of the dielectric only and then to the inside of the dielectric only. While no further reduction in noise was obtained by coating the outside only, the cable signal due to mechanical flexing was markedly reduced by coating the inside of the dielectric, provided the shield remained tight over the dielectric. Under these conditions, the residual noise was reduced to less than 3 millivolts peak-to-peak. By coating both inside and outside of the dielectric with the graphite suspension, the noise was almost completely eliminated.

In another series of tests, an experimental cable was made up from an outer braided shield, the same rubber-like dielectric as before, and an insulated central conductor. This cable was found to be quite noisy and was not materially improved by applying the graphite suspension to either the inside or outside of the dielectric.

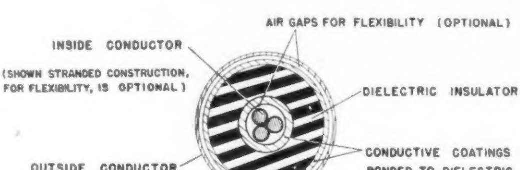
Analysis of these results, in combination with other reported data on cable noise, led to the formulation of a theory that describes completely the mechanism of noise generation in instrument cables. According to this theory, the noise signals are due to currents set up in the cable when static charges are separated at the surfaces of the dielectric. To free the cable of these unwanted signals, it is only necessary that the inside and outside surfaces of the dielectric be entirely covered by a well-bonded conductive coating.

Whenever a metal makes intermittent contact with a solid dielectric, a separation of electrical charges takes place, just as when two different dielectrics are rubbed together. Friction is not necessary for this effect, but it increases the amount of separated charge, probably by insuring better mechanical contact before separation. Thus, as a small area of the cable shield separates from the dielectric, a surface charge is left on the dielectric, and an opposite "bound" charge is left on the shield. As the air gap increases, the charge on the shield becomes increasingly "free", and a portion of this charge is redistributed by flowing through the terminal impedance of the cable, so that it ultimately appears on the central conductor, at a point opposite the separated charge on the dielectric. It is this flow of current through the terminal impedance of the cable that develops the "noise voltage." It is apparent that the process can also take place when the inner conductor, or both conductors, are free to separate from the dielectric.

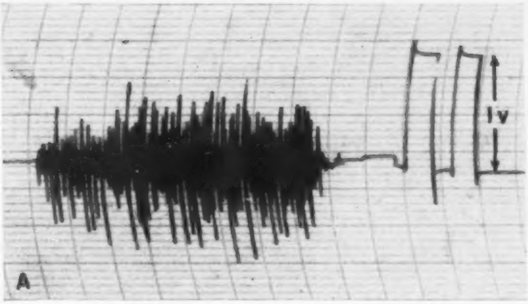
This theory of cable noise production seems to be confirmed by experimental results obtained at NBS. For example, signals generated in the manner described are, in theory, limited by the maximum density of surface charge possible without breakdown of the gas (usually air) between the cable dielectric and the separated conductor. When the noise voltage generated by this maximum theoretical surface charge is calculated from the electrical constants of the system, it is found to be not greatly in excess of some of the experimental data. Several other theoretical predictions have been verified by simple experiments. Thus, as predicted by the theory, the voltage generated by a sudden separation of one of the cable conductors from the dielectric rises suddenly to a peak followed by an exponential decay. Moreover, both the theory and experimental observations indicate that the initial amplitude of the recorded peak is proportional to the area of cable affected, inversely proportional to the total cable capacitance (including any parallel capacitances), and is reduced for a given surface charge if the allowed relative motion between the movable conductor and the dielectric is reduced. It is also found, both theoretically and in practice, that the initial amplitude of the peak is independent of the terminal resistance of the cable, provided this resistance is high enough to produce noise pulses of duration sufficient with respect both to the time required for separation and the high-frequency response of the electrical system.

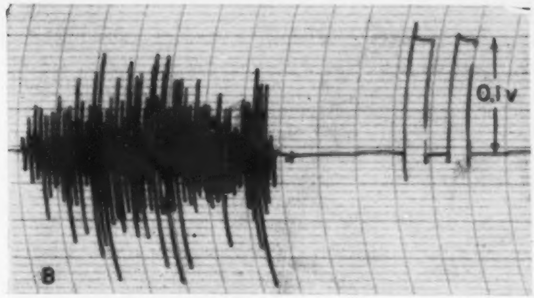
Experiments at NBS have shown that the resistance of the conductive coating need not be especially low. In fact, it has been found that a conductive coating having a resistance of the order of 1 to 50 megohms per linear inch of cable reduces the unwanted cable signals by a factor of 500 or more.

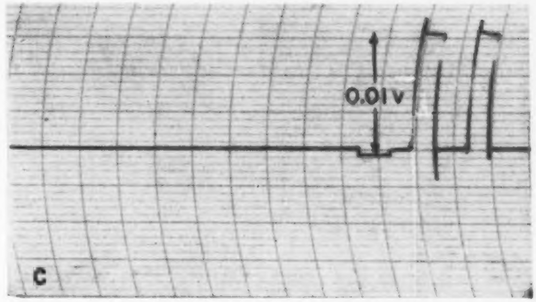
Various types of conductive paints, suspensions of graphite, and conductive rubbers that may be used for the conductive coating are available commercially, and several patents have been issued on methods for bonding such coatings to a cable insulator. One method for making noise-free cable that appears to have commercial possibilities consists in extruding concentric layers of conductive rubber, nonconductive dielectric, and more conductive rubber over a metallic conductor, preferably stranded for flexibility. All conductors of a multiconductor cable could be treated in this manner.



Cross-sectional diagram showing the structure of the noise-free coaxial cable developed by the National Bureau of Standards.







Noise signals generated by severe whipping (first half of each trace) of three types of coaxial cable show the great reduction in noise when the noise-free cable (C) developed by the National Bureau of Standards is used. A: microphone cable, 0.070-in. outside diameter. B: RG 62/U cable, 0.24-in. outside diameter. C: NBS experimental noise-free cable, 0.08 in. outside diameter. The two square waves at the right of each trace are for calibration purposes; their corresponding voltage values are indicated.

Neither the inside conductor nor the outside shield need fit tightly; in a flexible cable they should preferably be somewhat loose. If desired, a protective insulating outside jacket may be added; this jacket would not require a conductive coating. There appear to be no limitations on how small such a noise-free cable can be made.

Until noise-free cable becomes commercially available, short lengths—up to 6 feet—can be made by laboratory workers for their own use by combining parts of three different kinds of cable that are easily obtained. Lamp cord composed of stranded copper conductors between 0.006 and 0.007 inch in diameter can be used to make the central conductor. The shield can be obtained from microphone or phonograph pick-up cable about 0.070 inch in outer diameter and having a readily removable shield. For the dielectric, "push-back", hook-up wire with an AWG No. 20 conductor can be used. This wire should have a thin, rubber-like or impermeable plastic insulation and a solid conductor.

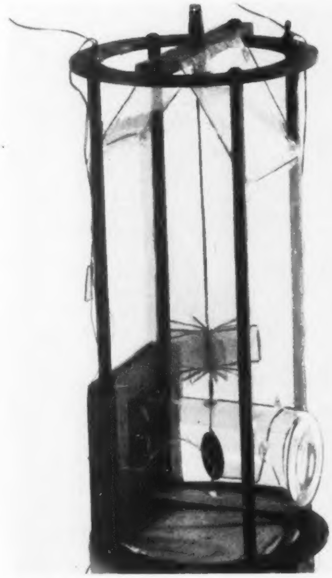
The hook-up wire is first stretched slightly to straighten it, and then the outer surface of the insulation of the wire, except for about 1 inch on each end, is coated with a conductive paint, and allowed to dry. Meanwhile, the shield is stripped from the microphone pick-up cable in such a way as to increase the inside diameter of the shield. This may be accomplished by pushing the shield toward the center of the cable and slipping it off after it has been compressed in length and correspondingly expanded. After the paint is dry on the outside of the hook-up wire, this shield may be slipped over it, but should be left loose. At this time the stranded copper can also be pulled out from the lamp cord. Five or six of the strands should be pulled out and tightly twisted by holding one end in a vise and the other in a drill chuck.

To make use of the insulation from the hook-up wire, the central conductor must first be removed. This may be done with a vise and a pair of pliers. After about one-half inch of the dielectric has been stripped from each end of the painted length of hook-up wire, the bare wire is held with the vise and pliers, stretched about 10 percent of its length (without stretching the insulation), and then pulled out of the insulation.

The next step is to apply the conductive paint to the inner surface of the insulation. First, a piece of transparent plastic tubing is taped to the outside of the dielectric tube about one-fourth inch from one end. The plastic tubing is connected to a vacuum line (mouth suction may be used instead), and the other end of the insulation is dipped in the conductive paint. When the paint appears in the plastic tube, the hollow dielectric is blown out enough to leave an opening for the inside conductor. (It may be necessary to apply the conductive paint twice in some cases.) After the painted conductor has dried, the stranded lamp-cord wire is pushed through the painted insulation, and the shielding is stretched over the entire length of the cable.

For the conductive paint, conductive suspensions in a vehicle designed to bond firmly to the cable dielectric have been found most suitable. Such special paints are available from most manufacturers of conductive paints and suspensions, but they are generally not sufficiently flexible. At NBS, a mixture of 3 parts by weight of finely divided (18 to 25 millimicrons) carbon black, 10 parts of a flexible adhesive, and 60 parts of methyl ethyl ketone solvent has been used with good results. The mixture must be kept tightly covered and requires considerable mixing to insure uniform distribution of the conductive material. This may be achieved by adding porcelain or glass balls to the mixture and rotating the closed container about its axis in a horizontal position for at least 24 hours after the initial mixing and for at least 15 minutes before use.

Thermal Rayleigh D[...] in



Center: Apparatus used at NBS to measure the torque exe[...] the t[...] the inner of two coaxial Dewar flasks the mirrored disk is[...]ded in[...] of second sound are set up within the resonant cavity, th[...] deflect[...] move along the ground glass scale. From the deviation [...] light s[...] Right: transformation of helium I (above) to helium II (b[...] Beca[...] sound, boiling stops at the transition point (2.19° K.).

USING a method analogous to that employed by nineteenth-century physicists to study ordinary sound waves, Dr. J. R. Pellam of the National Bureau of Standards has developed a very simple, yet highly accurate, mechanical technique for investigating "second sound", that unique wave-like process of heat transfer occurring only in helium II near absolute zero. The new technique, known as the thermal Rayleigh disk method, makes use of the torque exerted on a light disk suspended in the path of standing waves of second sound. It thus constitutes the first mechanical method for detection of this phenomenon. The NBS development not only provides an effective means for determining the velocity and intensity of second sound—of basic theoretical importance in low-temperature physics—but also appears actually to verify the presence of a superfluid in helium II and to open up an entirely new field of "quantum hydrodynamics" based on the peculiar heat-flow characteristics of this remarkable liquid.

Helium liquefies at 4.2° K, the lowest liquefaction temperature of any substance. Between the temperatures of 4.2° and 2.19° K, liquid helium behaves as a normal fluid. In this state it is known as helium I. At 2.19° K and below, however, helium I changes into the liquid form known as helium II. The characteristics of helium II are so unlike those of helium I or of any other fluid that it is often referred to as a fourth state of matter, or as the quantum fluid. Thus it acts as though it has no viscosity, flowing, apparently without friction, through virtually vacuum-tight openings and up the side of a containing vessel at remarkable speed in seeming defiance of gravity. Its direction of flow through narrow orifices may be controlled entirely by the introduction of temperature differences.

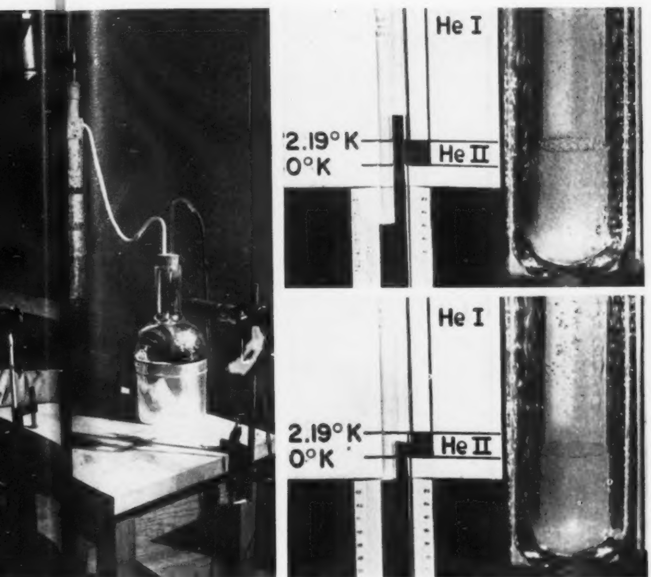
One of the unusual properties of helium II is its high thermal conductivity—three million times that of helium I and much greater than that of any other substance. In all other forms of matter, heat diffuses from point-to-point at a comparatively slow rate through the collision of one molecule with another. In liquids other than helium II this process is extremely slow. In helium II, on the other hand, heat is transferred many times faster than in other materials by means of a kind of wave motion analogous to sound and known as second sound.

The remarkable properties of helium II and the phenomenon of second sound have been explained by mathematical theories that indicate that helium II consists of two kinds of fluids. One portion is a normal fluid, similar in nature to helium I; the other is a superfluid, which accounts for the unusual effects observed. The atoms of the superfluid have had their energies reduced by cooling to the point where thermal motion has ceased, yet the attractive forces between them are not great enough to produce a rigid solid. According to current theories, the application of heat to some part of a quantity of helium II upsets the equilibrium between the two fluids, resulting in a migration of the superfluid atoms from cold to hot while the normal fluid atoms move from hot to cold. As the superfluid is assumed to have virtually zero viscosity, a sustained internal vibration between the fluid components becomes possible, and this internal convection type of wave propagation constitutes second sound.

Since second sound is basically a "concentration wave", consisting of a progressive change in the relative proportions of normal fluid and superfluid at any point in the liquid, it has until now been detected only by temperature-sensitive devices, such as a bolometer. Neither pressure nor velocity microphones could be used because the two fluid components oscillate exactly out of phase, and there is no net transfer of mass or momentum. The thermal Rayleigh disk method for studying second sound is unique in that it utilizes the mechanical forces produced by the streaming of the normal and superfluid atoms about a disk placed in the path of the waves. The elaborate electronic equipment previously required for research in second sound is thus eliminated.

The Rayleigh disk was originally developed by Lord Rayleigh in 1880 for detecting and measuring the strength of ordinary sound waves. Its operation depends on the tendency of a disk or other flat object when freely suspended to aline itself crosswise to the direction of fluid flow. This tendency results from distortion of the stream lines of fluid flow about the disk, which causes differences in the pressure exerted on the

D in Liquid Helium II



ue exe the thermal Rayleigh disk by waves of second sound. Within disk is ded inside of a resonant cavity (left). When standing waves ity, th deflects slightly; this causes a beam from the light source to iation ight spot on the scale, the torque on the disk is computed. m II (Because heat is transferred rapidly in helium II by second .).

disk by the fluid at various points. Since the torque exerted on the disk depends on the kinetic energy distribution of the fluid about the disk—that is, on the square of the particle velocity—the direction of particle flow does not affect the torque exerted on the disk, and two opposing currents, such as are presumed to occur in second sound, do not mutually cancel.

The principle of the Rayleigh disk is thus ideally suited to experimental verification of the two-fluid theory of helium II. If, as has been postulated, helium II consists of a mixture of normal fluid and superfluid, and second sound consists of a two-way migration of superfluid and normal fluid atoms in opposite directions, then a light disk freely suspended in the path of second sound should rotate toward a position perpendicular to the path of the heat flow, even though there is no net transfer of helium II in either direction.

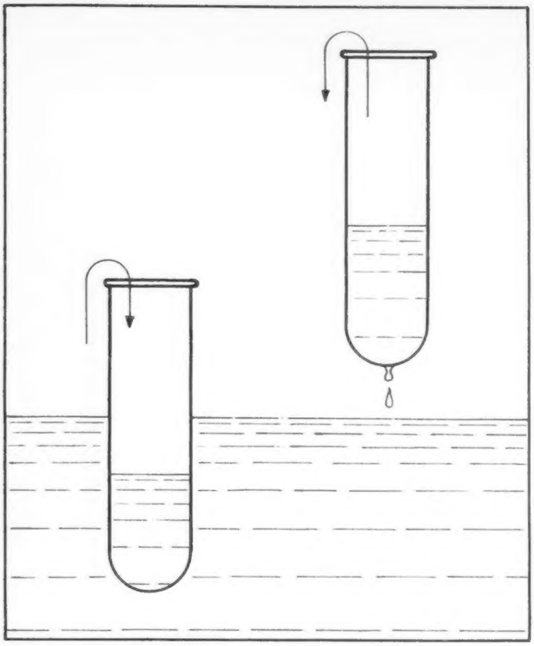
In the course of a continuing investigation of the low-temperature properties of matter at NBS, a thermal Rayleigh disk apparatus was set up to determine experimentally the validity of these conclusions. The subsequent measurements were made by Dr. Pellam, assisted by W. B. Hanson of the NBS staff. In this apparatus, a light-weight mirrored disk, 0.5 inch in diameter, is suspended by a thin torsion wire at the midpoint of a horizontally oriented cylindrical glass cavity containing helium II. Standing waves of second sound are set up within this cavity when heat oscillations of the proper frequency are introduced by means of an electrically heated carbon resistor strip that makes up one end wall of the cavity.

The resonant cavity, mirrored disk, and suspension are all immersed in a dewar of liquid helium II enclosed in a vacuum system. The temperature of the helium is obtained from the pressure above the liquid as indicated by a manometer. Initially the disk is placed at an angle of 45° to the direction of the flow of the waves of second sound. The small deviations of the disk from its initial equilibrium position at various temperatures and frequencies are then observed and measured by noting the resultant deflection of a light beam. The sharp response of the disk as the system is tuned through resonance verifies the existence of the internal mass flow of the two fluid components and the associated kinetic energy density. A light source projects the light beam down the axis of the resonant cavity onto the silvered disk, where it is reflected to fall in focus on a galvanometer scale. Very small deflections may thus be determined without difficulty. From these data, together with corresponding values of temperature and the geometry of the apparatus, the torque on the disk and the velocity and intensity of second sound are computed. Torques as small as 10^{-4} dyne-cm have been measured in this way.

The mirror-disk is cemented along its vertical diameter to a thin metal rod, which is supported in turn by a flat (0.0015 in. thick) copper ribbon. The metal rod hangs centrally through a small circular hole in the resonant cavity. Above this opening, and thus immersed in helium II but outside the resonant system, damping vanes composed of thin mica are cemented to the metal rod. A system very similar to that used for galvanometer suspensions is employed to protect the torsion ribbon from strain or shock when not in use. Only after the dewar system has been filled with liquid helium and cooled to helium II temperatures, thus eliminating all convection currents about the vanes, is the disk assembly raised to operating position.

The NBS experiments with the thermal Rayleigh disk have significant theoretical implications. In the first place, the response of the disk to the heat current known as second sound provides a convincing experimental verification of the two-fluid hypothesis of helium II. That the disk can detect these opposing currents, which do not affect a microphone, lends strong credence to the concept of the two fluids passing through each other in response to a difference in temperature between two points. Moreover, the amount of the measured torque and its variation with temperature correspond exactly with theoretical values computed on the assumption that the superfluid participates in the same streamline flow as do ordinary fluids.

Of even more fundamental significance is the generalized duality that the behavior of the thermal Rayleigh disk implies between the quantum thermomechanics of liquid helium II and the ordinary classical hydrodynamics of other liquids. In classical hydrodynamics, the relationship between velocity, height, and



When ordinary liquid helium (helium I) is cooled within 2.19 degrees of absolute zero, it is transformed into helium II, assuming properties that seem almost supernatural. If a test tube is placed in a container of helium II (left), the liquid helium climbs up over the side of the tube until the liquid surface inside the tube is level with that in the larger vessel. When the tube is raised (right), the helium climbs out until the liquid surfaces are again level or the tube is empty.

pressure at any point in a flowing liquid is given by Bernoulli's law as

$$\tfrac{1}{2}\rho V^2 + \rho g h + p = \text{constant}$$

(where ρ is the density of the liquid, V is its velocity, h is the height above a given reference point, and p is the pressure upon the liquid). A more general expression, applicable to the two-fluid counterflow of second sound in helium II, was developed on the basis of the two-fluid theory by Dr. Pellam shortly before the Rayleigh disk experiments were begun at NBS. It takes the form

$$\tfrac{1}{2}\rho V^2 + \rho g h + p + \frac{1\rho_n}{2\rho_s}\,\frac{\dot{H}^2}{(\rho S T)^2} = \text{constant},$$

where ρ_n and ρ_s are the densities of the normal fluid and superfluid, respectively; $\dot{H}^2$ is the rate of heat transfer, S is the entropy, and T is the absolute temperature. Here the final additional term relates the hydrostatic pressure of the two fluids to the density of the heat current that constitutes second sound. The generalized Bernoulli expression has now been confirmed by measurements of the torque on the disk. Thus, for every classical experiment in hydrodynamics, there presumably exists the quantum parallel in helium II where heat flow replaces mass flow. For example, recent experiments at NBS have shown that a pitot tube as well as a Rayleigh disk responds to the heat current in helium II. The thermal Rayleigh disk provides a means of investigating further the hydrodynamic flow of the normal and the superfluid.

The precision of the NBS Rayleigh disk apparatus is such that it provides a new quantitative method for measuring many properties of liquid helium II. Some, like second sound intensity, had never before been measured. Even such thermodynamic properties of helium II as specific heat (c_v) have been determined by the disk technique with greater accuracy than was previously possible. The precision of measurement has in fact reached the point where the thermal Rayleigh disk functions as a calorimeter, measuring heat capacity in an isothermal system in terms of the small temperature fluctuations of second sound. Such measurements by ordinary methods are extremely difficult at temperatures near absolute zero because of the very small amounts of heat involved, and the troublesome effects of the creeping helium film. For measurement of the other thermodynamic properties of liquid helium II, a semipermeable thermal Rayleigh disk, which responds selectively to the two fluid components, has been introduced. Work in this field is being continued at NBS, and several new approaches to the quantum hydrodynamics of helium II are being explored.

For further technical details, see Thermal Rayleigh disk measurements in liquid helium II, *by John R. Pellam and William B. Hanson, Phys. Rev.* (January 15, 1952).

Transfer Standards for Audio-Frequency Tests

As a part of a program to increase the range and accuracy of electrical measurements at audio frequencies, the National Bureau of Standards has developed highly accurate electrothermic transfer methods for the measurement of voltage and current. Designed primarily for the testing of ammeters and voltmeters, the transfer methods make possible accuracies approaching 0.01 percent over wide ranges of current and voltage at audio frequencies. They thus enable NBS to meet growing demands for the accurate standardization of electrical instruments at frequencies higher than the commercial power frequencies at which these services have hitherto been available.

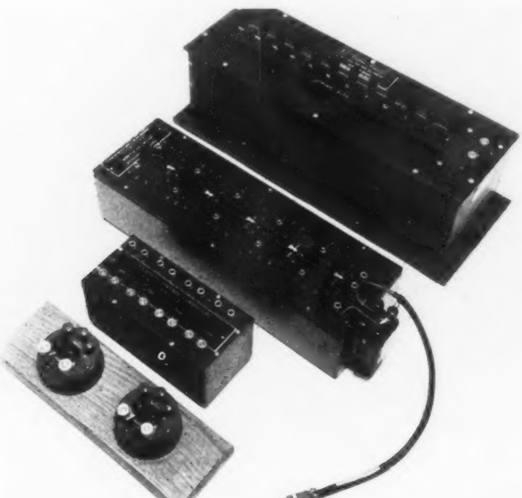
As the custodian of the national standards of physical measurement, NBS has the responsibility of insuring that the units of measurement used in science and industry are constant throughout the years and uniform throughout the Nation. The Bureau has developed very precise standards of resistance and voltage whose values are established by absolute measurements that fix the relations between the electrical units and the fundamental mechanical units of length, mass, and

Standardization of an a-c voltmeter in the National Bureau of Standards electrical instruments laboratory. At right, the scale of the instrument under test is being accurately read by means of a specially designed projection device directly above the instrument. At left, the value of the direct voltage required to give the same response in an electrothermic transfer standard (in front and at lower right of first panel) is being determined.

time. From these basic absolute electrical standards, the Bureau has derived other standards for all electrical quantities in use today. Accurate comparison of the secondary or working standards of other laboratories with the primary standards thus calibrated makes possible the high degree of accuracy and uniformity that prevail in electrical measurements throughout American science and industry. As higher audio frequencies are being used increasingly in aircraft, induction furnaces and heating, and various electronic devices, it has become necessary for NBS to develop special equipment and transfer standards for tests of instruments operating in this range. As the fundamental electrical units are maintained by d-c standards, all a-c measurements of voltage, current, and power are actually based on transfer instruments, which are standardized on direct current and then used on alternating current.

The electrothermic transfer standards used at NBS are thermal converters, often called thermocouples or thermoelements. Each thermal converter consists of a conductor, heated by the alternating current to be measured, and a thermocouple, one junction of which is thermally connected to the heater. The value of the direct voltage produced in the thermocouple thus depends on the value of the alternating current measured. Although such thermal converters have commonly been used for measurements at radio and higher frequencies, it has not been generally realized that they provide the basis for a particularly simple form of electrothermic instrument that responds equally well to direct and alternating current at audio frequencies. NBS investigations have shown that certain selected and tested commercially available thermal converters can be used for transfer work to an accuracy of 0.01 percent at currents from 1 milliampere to 50 amperes over the audio-frequency range from 20 to 20,000 cycles per second. Experimental and theoretical studies recently carried out by Francis L. Hermach of the NBS electrical instruments laboratory have brought out a number of the factors governing the transfer accuracy, particularly at these comparatively low frequencies. As the requirements imposed by these factors can readily be met, the NBS studies have made possible the specification and purchase of commercial thermal converters having the required accuracy over wide current ranges at audio frequencies. Two forms of multirange voltmeter elements with ranges from 0.2 to 750 volts, consisting of commercially obtainable resistors in series with the heater of a selected thermoelement, have been constructed at NBS, and their transfer performance has been carefully studied to make possible accurate alternating-voltage measurements.

In standardizing electrical instruments, these transfer standards are used for two distinct types of tests: one for instruments that respond to direct as well as alternating current, the other for those that cannot be used with accuracy on direct current. Instruments of the first type are generally given a transfer test that directly determines their ac-dc differences. The instrument under test and the NBS standard are connected so as to "see" the same electrical quantity successively on alternating and direct current. In each case the current is adjusted to produce the same deflection in the test instrument, and the response of the standard is observed. From these observations the ac-dc differences of the test instrument are computed by simple formulas. These differences are relatively permanent, and their measurement need not ordinarily be repeated.



Thermal converters and voltmeter elements used at the National Bureau of Standards for the testing of ammeters and voltmeters at audio frequencies. To increase the range and accuracy of measurements at these frequencies, NBS has developed highly accurate electrothermic transfer methods.

Thus, when combined with a d-c test, this procedure gives more information than would an a-c test alone.

In the a-c test, the standard and test instruments are connected together on alternating current, and the current is adjusted for the required response of the test instrument. The response of the standard is observed, and the standard is then switched to direct current, which is adjusted to give the same response. The value of the direct current or voltage required to give this response is then measured with a potentiometer and accessory apparatus.

The results obtained at the National Bureau of Standards show that, when properly used, certain thermal converters are capable of a transfer accuracy approaching that of the best electrodynamic and electrostatic instruments and are useful over wide frequency, current, and voltage ranges. For laboratories that may wish to set up similar equipment, the sets of tested thermal converters at NBS make possible direct determination of the transfer performance of other converters to high accuracy. At present, comparison with the Bureau's converters is recommended if accuracies better than about 0.1 percent are desired. While the equipment used with the standards is not portable, the transfer standards themselves are, and they have been used with a portable potentiometer for measurements of voltage and current at other locations.

For more complete information, see Thermal converters as ac-dc transfer standards for current and voltage measurements at audio frequencies, *by F. L. Hermach, J. Research NBS* **48** (Feb. 1952) RP2296.

Molecular Microwave Spectra Tables

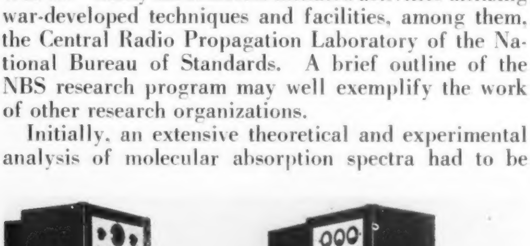
IN RECOGNITION of the steadily increasing interest in molecular spectra investigations by microwave frequency techniques, the National Bureau of Standards has recently compiled a set of molecular microwave spectra tables, which is to be published as an NBS Circular. The computation and tabulation has been conducted by P. Kisliuk and C. H. Townes (Columbia University and NBS) in cooperation with the NBS Microwave Standards Laboratory. The tabulation comprises 99 molecules from the simpler diatomic molecules to more complex combinations such as chlorotrimethyl methane (C_4H_9Cl). About 1,800 microwave absorption lines are included that range in frequency from 2,000 to 150,000 megacycles.

Rapid progress in microwave spectroscopy has been made possible by the development and use of microwave frequency equipment during and since World War II. Many laboratories initiated activities utilizing war-developed techniques and facilities, among them, the Central Radio Propagation Laboratory of the National Bureau of Standards. A brief outline of the NBS research program may well exemplify the work of other research organizations.

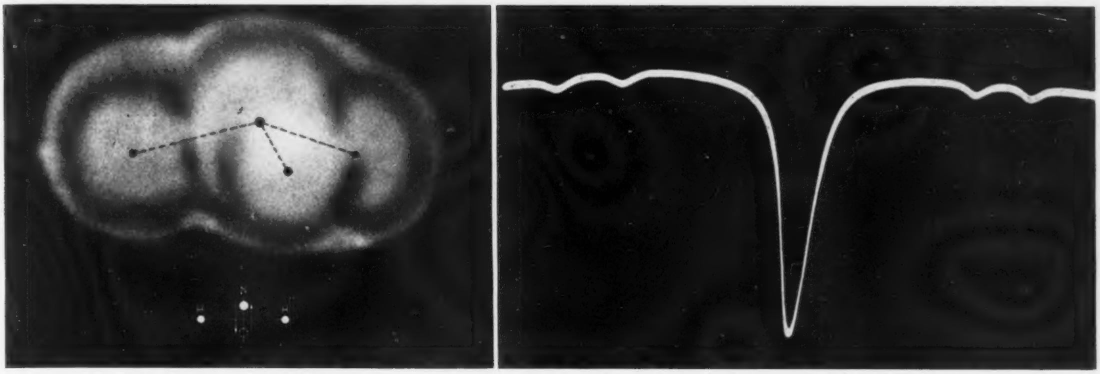
Initially, an extensive theoretical and experimental analysis of molecular absorption spectra had to be conducted. One result of this series of experimental studies was the discovery of 150 absorption lines of the three deuterated isotopes of ammonia. Isotopic identities have been assigned experimentally to most of these lines and, as a result, the spectral tables have been extended downward to the lower frequencies.

At NBS, the absorption spectra of a known gas is identified by injecting microwave energy of controllable and determinable frequency through a low-pressure cell containing the gas. The radio energy transmitted through the gas is then recorded as a function of frequency. Relatively negligible absorption occurs over the full range of frequencies except in those regions centered around the characteristic absorption frequencies of the gas. At these points, absorption maxima occur. The complete spectrum that occurs is one of the identifying characteristics of the gas present or of the types of molecules involved in the absorption. These characteristics are invariant for all time. Once the properties of a number of gases have been determined in this way, the results tabulated and made available, the data may be used in qualitative and quantitative chemical analysis just as are the tables of optical, infrared, and ultraviolet spectra.

The future employment of microwave spectroscopy can be optimistically forecast in view of the present role played by the ultraviolet and infrared methods of investigation. Although these methods determine the characteristics of chemical atoms and compounds present in the gas under test, the small effects produced by isotopic substitution are usually beyond their



Demonstration set-up of the NBS molecular microwave spectroscopy apparatus. A microwave oscillator (on truck at right) generates an r-f signal at 23,870 megacycles. The radio energy is directed toward the absorption cell (center) which contains ammonia gas. The cell shown is actually much shorter than one used in practice. A crystal pickup (left of cell) detects the r-f signals passing through the cell. The crystal voltages are amplified by equipment mounted in the rack at the left. The rack at the right contains power supplies, square wave generators, and monitors. The vacuum system and gas supply equipment are located below the truck carrying the absorption cell.



The panel at the left shows the apparent configuration of the NH_3, molecule. The four constituents form a pyramid with nitrogen at the apex. In an excited state, the nitrogen oscillates through a plane formed by the three hydrogen atoms at a characteristic vibration rate. The panel at the right is an oscillogram of an r-f signal that is varied in frequency as it passes through an absorption cell containing ammonia. The frequency of the generated signal is equal to the characteristic vibration frequency of the gas where the absorption maximum shown results. This is indicated by the dip in the generated curve. The curve also shows the fine line structure of the gas.

limit of resolution. For example, the optical methods would become very complex in trying to distinguish between the spectra of ND_3 and NH_3. However, the substitution of three deuterium atoms for the three hydrogen atoms of ordinary ammonia is accompanied by a very large change in frequency of the main group of microwave absorption lines. Thus, by using microwave techniques, the 1,500-megacycle line of ND_3 can readily be distinguished from the 24,000 line of NH_3. Another example is the spectra of $N^{14}H_3$ and $N^{15}H_3$. The 1,000-megacycle frequency difference between these two nearly identical isotopes is easily distinguished by the microwave technique.

The publication of the new NBS circular was possible only through the cooperation of those presently working in this phase of spectroscopy. Many of the molecular data were acquired through private communications with researchers throughout the United States and the United Kingdom. In its present form, the tables represent a major portion of the data reported prior to November 15, 1950.

The material presented in the NBS compilation is divided into three tables and three indexes. Table I is an alphabetical listing of the molecules by their chemical symbols and includes the primary information. All available molecular constants needed to interpret the spectra are given; these include rotational constants, dipole moments, quadrupole coupling constants, and rotation-vibration interaction constants. Data are given for molecules in their ground vibrational state and also in their excited vibrational states when available. Hyperfine components are also presented. Frequencies listed to the nearest megacycle were generally measured with a cavity wavemeter and are subject to an error of 10 or more megacycles, whereas those given to a fraction of a megacycle are generally known to an accuracy of about 0.1 megacycle. In addition to the observed frequency and the transition assigned to each line, a calculated value for the intensity and references to the latest sources of data from each laboratory that has measured a line are incorporated.

Table II is a listing of the lines in order of their frequency, with sufficient information to locate them in Table I. The intensity of each line, obtained from either observed results or calculations, is noted as either strong, medium, or weak. Lines of maximum absorption coefficient less than 5×10^{-7} cm^{-1} are classified as weak, those from 5×10^{-7} to 10^{-5} cm^{-1} as medium, and those greater than 10^{-5} cm^{-1} as strong.

For easy calculation of quadrupole hyperfine structure, Casimir's function is tabulated up to $J=10$ and $I=9/2$ in Table III.

The three indexes placed at the end of the tables aid in cross referencing. Index 1 gives the molecules in the tables by their chemical symbol, empirical formula, structure or common formula, and the page on which the molecules may be found. An alphabetical listing of the molecules by their name and where they may be found in the tables appear in Index 2. Finally, Index 3 lists the various contributors to the tables and the molecules they have reported.

As in the early developmental periods of the optical methods of investigation, the microwave molecular technique is restricted because of the limited number of molecules that have been reported. Additions to the Molecular Microwave Spectra Tables will be published by the National Bureau of Standards as sufficient data become available. To be of great value, an endeavor of this magnitude can succeed only with the cooperation of all the laboratories presently engaged in this type of research. As a means to this end, all suggestions and additions for future editions of the tables will be gladly received by the Microwave Standards Section, National Bureau of Standards, Washington 25, D. C.

For further technical details, see National Bureau of Standards Circular 518, Molecular microwave spectra tables, *by P. Kisliuk and C. H. Townes, available from the U. S. Government Printing Office.*

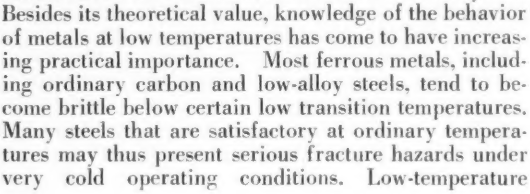
Microwave spectra of deutero ammonias, *by H. Lyons, L. J. Rueger, R. G. Nuckolls, and M. Kessler. Phys. Rev.* **81**, 630 (Feb. 15, 1951).

Nitrogen Content and Low-Temperature Brittleness of Steel

A RECENT investigation by the National Bureau of Standards provides valuable information on the effect of nitrogen on the brittleness of certain carbon steels at low temperatures. Results of fracturing V-notch specimens in Charpy impact tests indicate that increased nitrogen, if present as aluminum nitride, improves the low-temperature notch-toughness—lowers the temperature at which brittleness appears—in the steels studied. But nitrogen in the form of nitrides of iron or manganese is apparently detrimental from the same standpoint. The study was conducted by G. W. Geil, N. L. Carwile, and T. G. Digges of the NBS thermal metallurgy laboratory.

Various aspects of the influence of temperature on metals have been studied at NBS for a number of years. Besides its theoretical value, knowledge of the behavior of metals at low temperatures has come to have increasing practical importance. Most ferrous metals, including ordinary carbon and low-alloy steels, tend to become brittle below certain low transition temperatures. Many steels that are satisfactory at ordinary temperatures may thus present serious fracture hazards under very cold operating conditions. Low-temperature characteristics of metals may become particularly important in aircraft operating at high altitudes or in cold climates, in military vehicles and equipment for arctic use, and in refrigerating equipment.

This Charpy-type impact-testing machine is used to measure the notched-bar impact properties of steel and other metals. The notched specimen (operator's left hand) is supported at both ends in the anvil of the testing machine, and is broken by a single blow of the pendulum (above), which strikes the specimen at its center on the side opposite the notch. After breaking the specimen, the pendulum swings through between its supports. The difference between height of fall and height of rise of the pendulum gives a measure of the energy required to break the specimen.



The transition temperature from ductile to brittle behavior goes down as the aluminum nitride content goes up, according to a recent National Bureau of Standards study of certain 0.3-percent carbon, 0.2- to 0.3-percent silicon steels. Solid circles—1.6-percent manganese steels not treated with aluminum; open circles—1.6-percent manganese steels treated with aluminum; triangles—0.9-percent manganese steels treated with aluminum.

This low-temperature increase in brittleness, or loss of toughness, is generally accompanied by a decrease in ductility, by a decrease in energy absorbed in fracturing, and by a change in appearance of the fracture surface; this surface is fibrous in appearance in higher-temperature fractures but becomes granular in fractures occurring at lower temperatures. Transition temperatures depend on many factors, including chemical composition, the manufacturing process, subsequent thermal and mechanical treatment, and method of applying stress. Even if it is not introduced intentionally, a certain amount of nitrogen normally finds its way into steel in the course of manufacture. Knowledge of the effect of nitrogen on low-temperature brittleness, as well as on other steel characteristics, therefore becomes important.

The samples studied at NBS were of 0.3-percent carbon steels containing 0.9 or 1.6 percent of manganese, 0.2 to 0.3 percent of silicon, and variable nitrogen. Included was one aluminum-treated series. Notched specimens were fractured in impact at temperatures ranging from −196° to +100° C (−320° to

+212° F). The aluminum-treated steels tested showed much better low-temperature notch-toughness than the steels not so treated; transition temperatures, at which behavior changed from ductile to brittle, were approximately 30° to 50° C (54° to 90° F) lower for the aluminum-treated specimens. Transition temperatures ranged from about −45° or −50° C (about −50° to −60° F) for the nonaluminum-treated steels to about −80° or −95° C (about −110° to −140° F) for the aluminum-treated steels. In the latter the nitrogren was present as aluminum nitride, and transition temperatures decreased with increasing aluminum nitride content.

Reported findings by various past investigators of the effect of nitrogen content on low-temperature properties of steels have been inconsistent. Some investigators have reported decreased toughness and higher transition temperatures with increased nitrogen, while others have reported no appreciable effect. Other researchers have suggested that nitrogen may be beneficial if present in the form of aluminum nitride. The new NBS study, indicating that nitrogen is beneficial to low-temperature notch toughness if present as aluminum nitride but detrimental if in the form of other nitrides, tends to explain and reconcile the inconsistent earlier reports.

For further technical details, see **Influence of nitrogen on the notch toughness at low temperatures of heat-treated 0.3 percent carbon steel,** *by G. W. Geil, N. L. Carwile, and T. G. Digges. J. Research NBS* **48** **(March 1952).**

Symposium on Electrostatic Information Storage

A SYMPOSIUM on Williams Electrostatic Storage, the first assembly of its kind, was held at the National Bureau of Standards on December 13 to 14, 1951. In attendance were scientists from practically every electronic digital computer activity in the United States, Canada, and England having an interest in electrostatic information storage. Registrants included 42 from commercial organizations, 15 from universities, and 58 from government laboratories. Fourteen informative papers were presented, and several active discussion periods added to the value of the symposium. The conference was organized and conducted by the staff of the NBS electronic computers laboratory, where the Williams technique is one of the two information-storage methods being used with SEAC (the National Bureau of Standards Eastern Automatic Computer).

Named for its originator, Professor F. C. Williams of the University of Manchester (England), the Williams electrostatic storage technique uses ordinary cathode-ray tubes to store information in electrical coded-pulse form. The pulses are stored as charged spots, which are automatically restored to full strength at regular intervals, at a large number of positions on the face of the tube. When information stored at a particular location is wanted, it can be obtained very rapidly by suitably directing the electron beam to the points of interest on the tube face. Because it provides unusually fast access to stored information, as well as fair storage capacity, the Williams storage technique has excited considerable interest among designers of "memories" for electronic computers. NBS has been active in research and development work on the still-new method, and the Williams memory now used with the Bureau's SEAC can store 512 "words" of 48 digits each.

"SEAC as a case study in Williams storage" was the topic of the first session of the symposium, a session at which S. N. Alexander, chief of the NBS electronic computers laboratory, presided. Three subsequent sessions were devoted to "Storage mechanisms", Professor Ralph Meagher (University of Illinois) presiding; "Circuit problems", Professor V. G. Smith (University of Toronto) presiding; and "Cathode-ray tubes", R. T. Young (NBS electron tube laboratory) presiding. J. H. Wright of the NBS computer staff served as symposium chairman.

The symposium met a widely felt need for exchange of up-to-date information on the current status of the Williams technique. Theoretical analyses, experimental data, operational experience, and ideas were presented and discussed. Agreement was general among those attending that papers presented by Professor T. Kilburn of the University of Manchester, an associate of Professor Williams, were particularly valuable. A feature of the symposium was an open house in the SEAC building, at which automatic troubleshooting routines used with the SEAC memory system were demonstrated.

Publication of symposium proceedings not planned. The following papers were given (in order of presentation): "The SEAC electrostatic memory", W. W. Davis (NBS); "Diagnostic test routines", D. C. Friedman (NBS); "Theory of storage", Prof. T. Kilburn (U. of Manchester); "Some experiments on the Williams-type memory", B. Norris and R. Klein (Argonne National Laboratory); "Space charge effects", J. Kates (U. of Toronto); "Triode theory of storage", A. W. Holt (NBS); "Focus-Defocus method", (Telecommunications Research Establishment, England) read by Mr. G. H. Percy-Woolston; "The ORDVAC memory system", E. L. Hughes (U. of Illinois); "Read-around-ratio tests", A. H. Vanderburgh and C. E. Reesor, (Ferranti Electric, Canada); "A redundant electrostatic storage system for digital computers", P. C. Sherertz (Naval Research Laboratory); "Amplifier design and C. R. T. displays", Prof. T. Kilburn, (U. of Manchester); "Operational report on ORDVAC memory", J. M. Wier, (U. of Illinois); "The General Electric (of England) CR tube for Williams storage", read by B. W. Pollard (Ferranti, Ltd., England); "Survey of cathode-ray tube problems", D. C. Friedman, (NBS). The following unscheduled talks were also given: "Cathode-ray tube development for the Bureau of Ships", L. Swedlund (RCA); "Cathode-ray memory experience", J. Richardson (Los Alamos).

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards, volume **48**, number 2, February 1952 (RP2291 to RP2300, incl.).

Technical News Bulletins, volume **36**, number 2, February 1952. 10 cents.

CRPL-D90. Basic Radio Propagation Predictions for May 1952. Three months in advance. Issued February 1952. 10 cents.

Research Papers

Reprints from Journal of Research, volume 48, No. 1, January 1952

RP2279. Absolute viscosity of water at 20° C. J. F. Swindells, J. R. Coe, Jr., and T. B. Godfrey.

RP2280. On some functionals of Laplacian processes. R. Fortet.

RP2281. Solubility of carbon in 18-percent-chromium—10-percent-nickel austenite. Samuel J. Rosenberg and Carolyn R. Irish.

RP2282. Uniformly best constant risk and minimax point estimates. Raymond P. Peterson.

RP2283. Sensitive mercury-level detecting unit for manometers. W. E. Williams.

RP2284. A note on bounds of multiple characteristic roots of a matrix. P. Stein.

RP2285. Binding energies for electrons of different types. Charlotte E. Moore and Henry Norris Russell.

RP2286. On the estimation of an eigenvalue by an additive functional of a stochastic process, with special reference to the Kac-Donsker methods. R. Fortet.

RP2287. Synthesis and physical properties of *n*-heptane and 2,2,4-trimethylpentane. Philip Pomerantz.

RP2288. Some general theorems on iterants. P. Stein.

RP2289. Ionization constant of 5-5′-diethylbarbituric acid from 0° to 60° C. George G. Manov, Kathryn E. Schuette, and Floyd S. Kirk.

RP2290. Infrared absorption spectra of five halomethanes. Earle K. Plyler and Nicolo Acquista.

Circulars

C517. Calibration of commercial radio field-strength meters at the National Bureau of Standards. Frank M. Greene. 10 cents.

Miscellaneous Publications

M202. Report of the thirty-sixth national conference on weights and measures. 50 cents.

Publications in Other Journals

Constant-amplitude oscillator. Norris C. Hekimian. Electronics (330 West Forty-second Street, New York 18, N. Y.) **24,** 164 (July 1951).

Radio Wave generation by multistream charge interaction. J. Feinstein and H. K. Sen. Phys. Rev. (57 East Fifty-fifth Street, New York 22, N. Y.) **83,** 405 (July 15, 1951).

Measuring power factor of low-loss dielectrics. J. L. Dalke and R. C. Powell. Electronics (330 West Forty-second Street, New York 18, N. Y.) **24,** 224 (August 1951).

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